



Searches for Supersymmetry at HERA



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On behalf of the H1 and ZEUS collaborations



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the Unification of Fundamental Interactions

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Outline

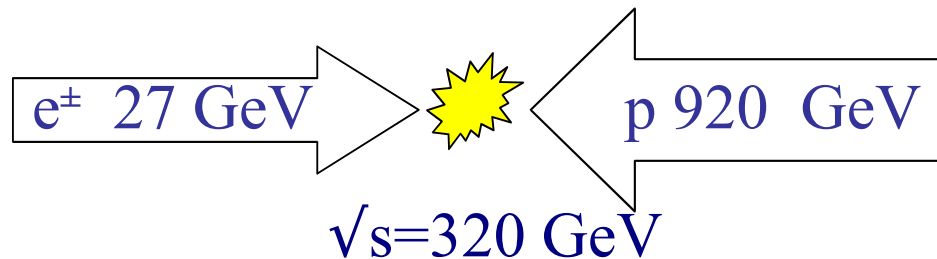
- HERA status
- RPV supersymmetry
- Searches for squarks
- Stop decays
- Search for gaugino production
- Searches for gravitinos
- Conclusions

brand new results!

Focus on recent results and updates since SUSY05.

→ For non-SUSY searches at HERA see talk by Linus Lindfeld

HERA Running



HERA I: 1993-2000

Luminosity: $\sim 130 \text{ pb}^{-1}$

85% e^+ , 15% e^-

HERA II since 2002:

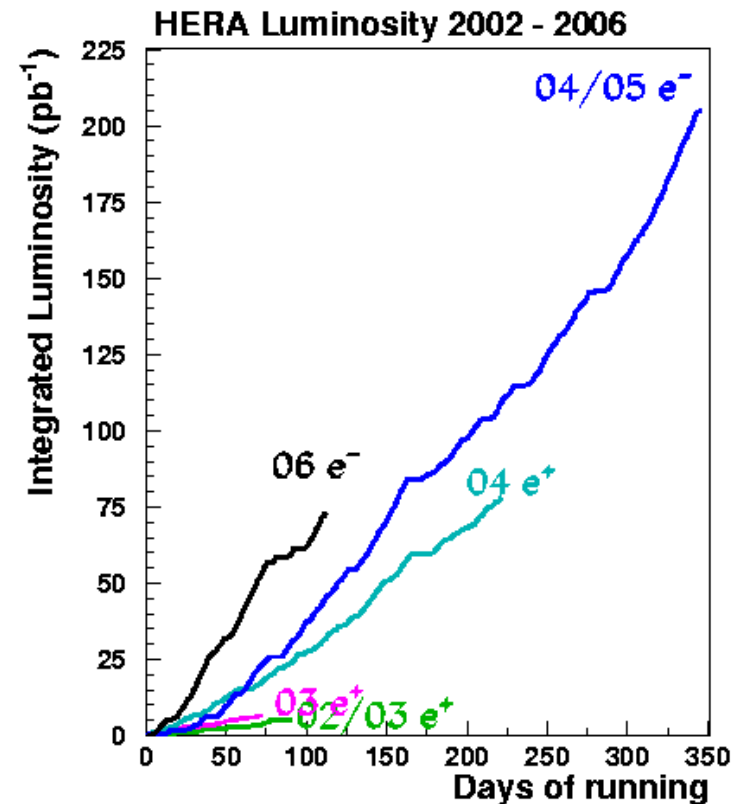
Instant. luminosity increased by factor 3

Polarised e^\pm beam: $\overline{P}_e \sim 36\%$

Luminosity: $\sim 240 \text{ pb}^{-1}$ until now

15% e^+ , 85% e^-

HERA II data analysis started. (This talk only HERA I data.)



Very efficient running
in 2004+2005+2006 (on-going)

RPV Supersymmetry

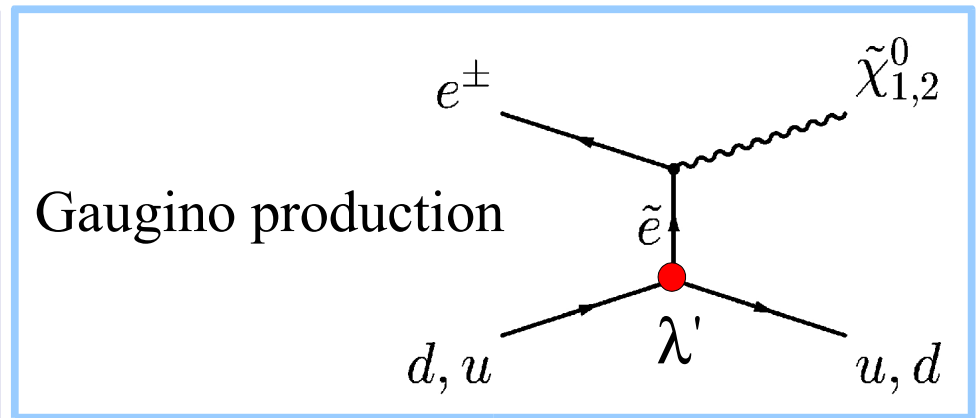
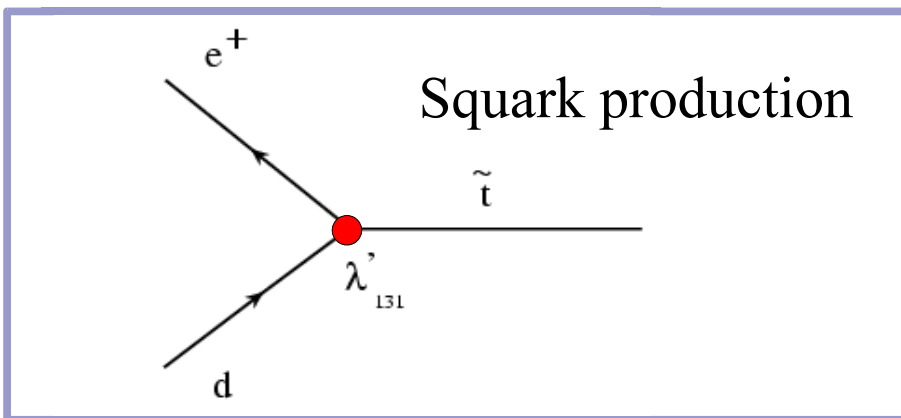
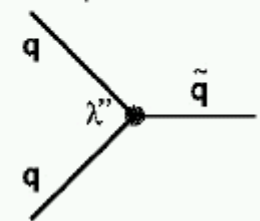
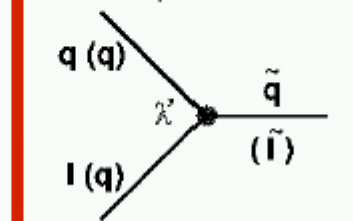
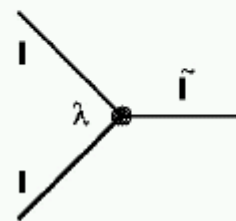
Multiplicative, discrete Symmetry: $R_p = (-1)^{3B+L+2S}$ +1 for SM particles
 -1 for SUSY particles

RPV: Allows single sparticle production; LSP can decay to SM particles

Additional trilinear terms in superpotential:

$$W_{RPV} = \underbrace{\lambda_{ijk} L_i L_j \bar{e}_k}_{\cancel{R}} + \underbrace{\lambda'_{ijk} L_i Q_j \bar{d}_k}_{\cancel{R}} + \underbrace{\lambda''_{ijk} \bar{u}_i \bar{d}_j \bar{d}_k}_{\cancel{R}} \dots$$

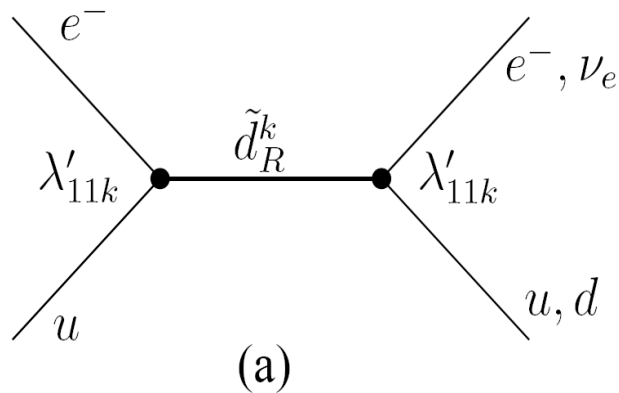
Leading order diagrams at HERA from λ'_{ijk} term.



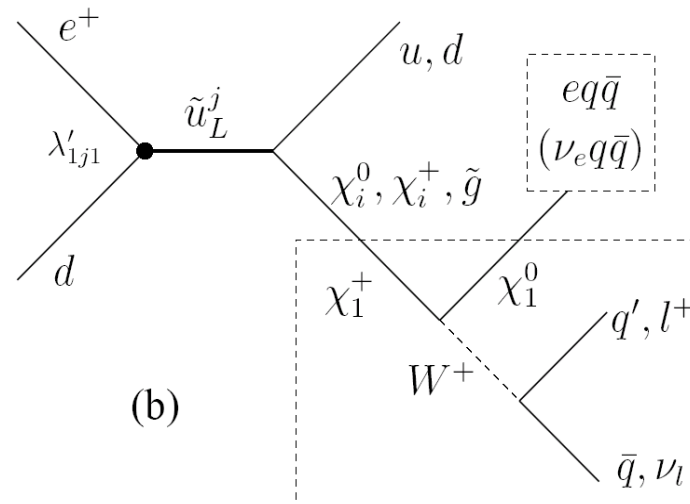
Reminder: H1 Squark Searches

Resonant squark production in s-channel. Squark masses up to $\sqrt{s}=320\text{GeV}$.

R_p -violating decay:



Example of gauge decays:



- Many final states considered:

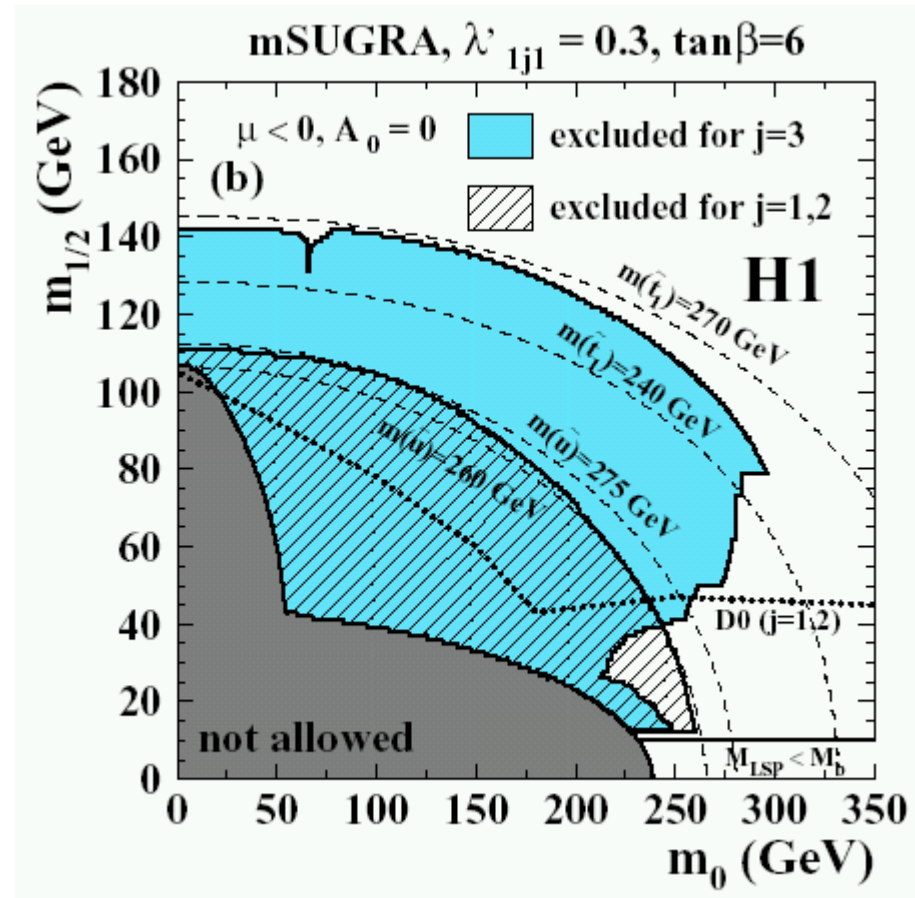
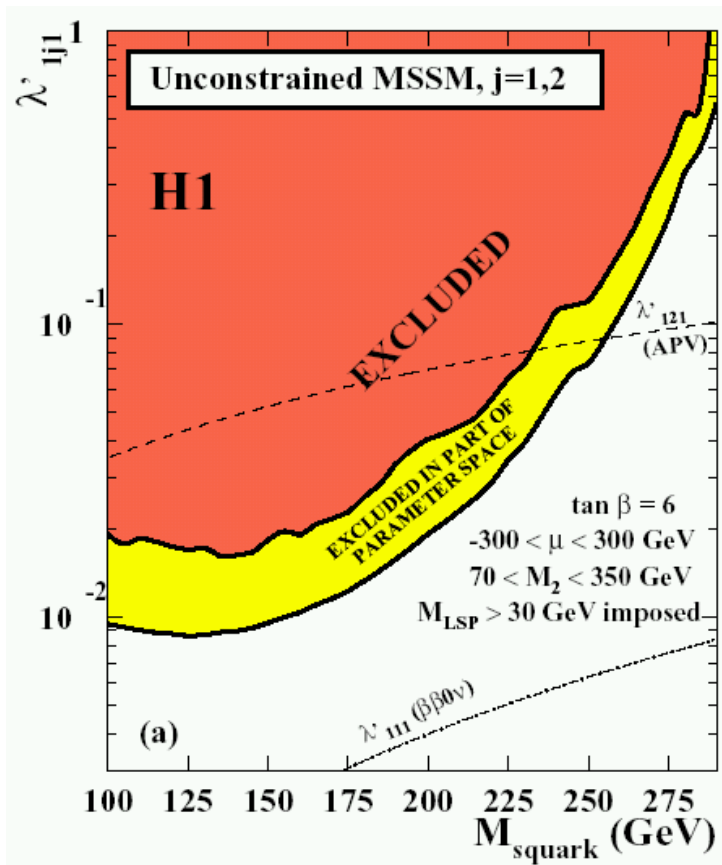
$$eq, \nu q, eMJ, eeMJ, e\mu MJ, \nu eMJ, \nu MJ, \nu\mu MJ \quad \sum \text{BR} \sim 100\%$$

- No deviation from SM observed in any of these channels.

→ Large region of SUSY parameter space can be excluded.

H1 Squark Searches Limits

Examples for λ'_{1j1} :



Very similar limits for λ'_{11k}

For strength $\lambda'=0.3$ squark masses up to 275 GeV excluded at 95% CL.

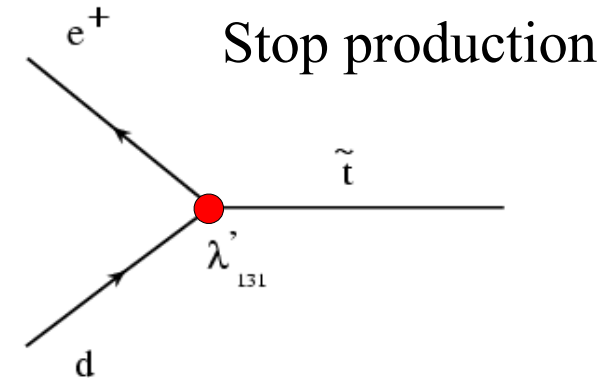
ZEUS Stop Search

MSSM parameter space:

$$100 \text{ GeV} < M_2 < 300 \text{ GeV}$$

$$-300 \text{ GeV} < \mu < 300 \text{ GeV}$$

$$\tan(\beta) = 6$$

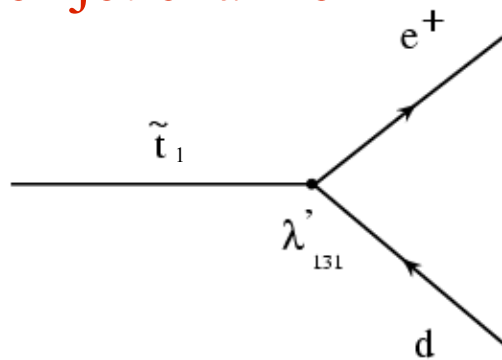


Stop is lightest squark in most of parameter space.

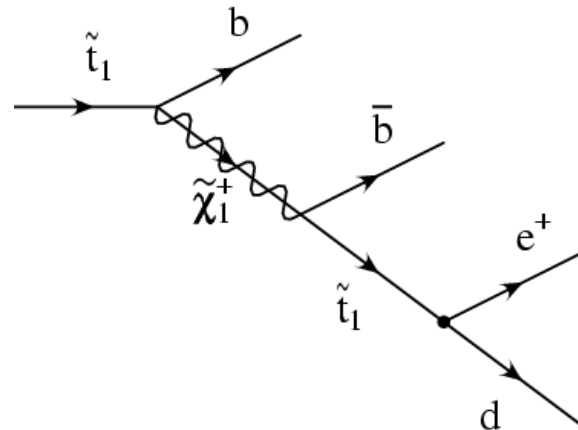
Dominant decay channels:

Electron channels

e^+ -jet channel

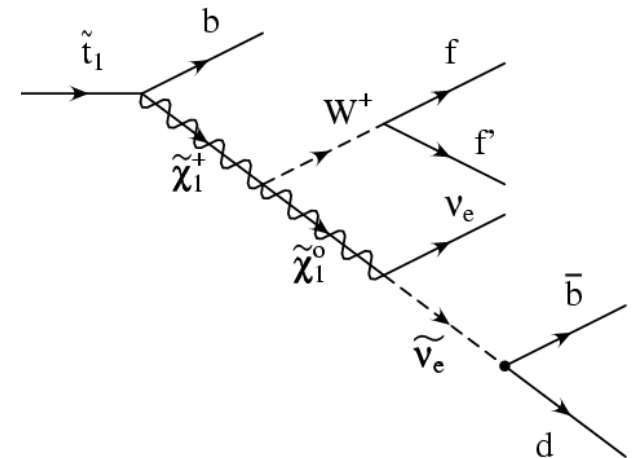


e^+ -multi jet channel



Neutrino channel

ν -multi jet channel



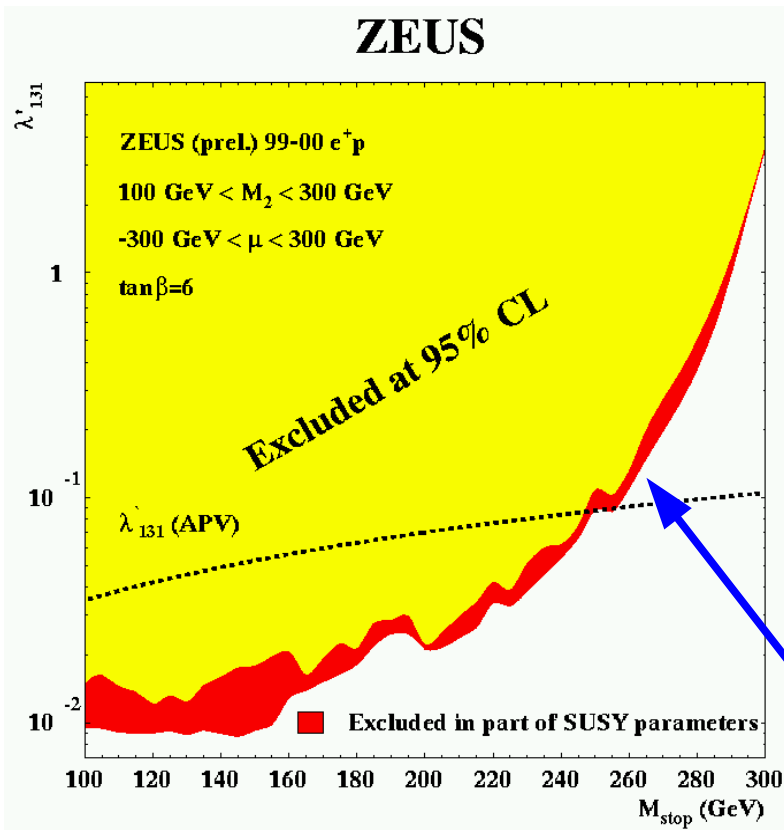
ZEUS Stop Search: Results

No deviation from Standard Model was found.

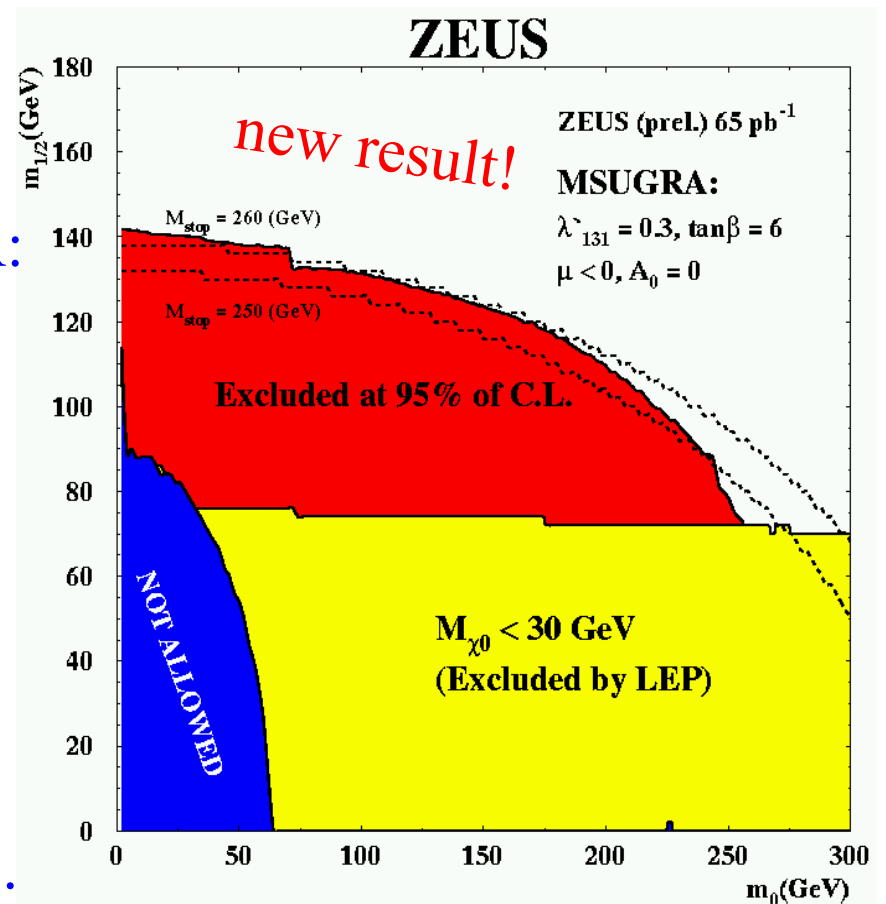
Calculate combined limits for three channels.

For $\lambda=0.3$ values up to $M_{\text{stop}}=270$ GeV can be excluded at 95% CL.

Scenarios where $\tilde{\chi}_1^0$ is not the LSP or $m_{\chi_0} < 30$ GeV were discarded.



Limit for mSUGRA:



Small influence of M_2 and μ (red region).

H1: Bosonic Stop Decay

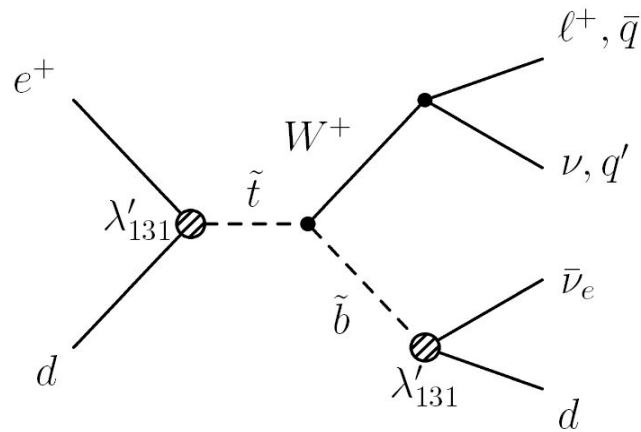
Mass spectrum complementary to previous squark search:

$$m(\tilde{b}) + m(W^\pm) < m(\tilde{t}_1) < m(\tilde{\chi}^0) + m(t), m(\tilde{\chi}^+) + m(b)$$

Reminder:

Excess seen by H1/ZEUS

- e/μ : [H1, Phys. Lett. B561 (2003) 241.]
- [ZEUS, Phys. Lett. B559 (2003) 153.]
- [H1, prelim., DIS04]
- τ : [ZEUS, Phys. Lett. B583 (2004) 1.]



Signatures:

jet+l+p_{T,miss}

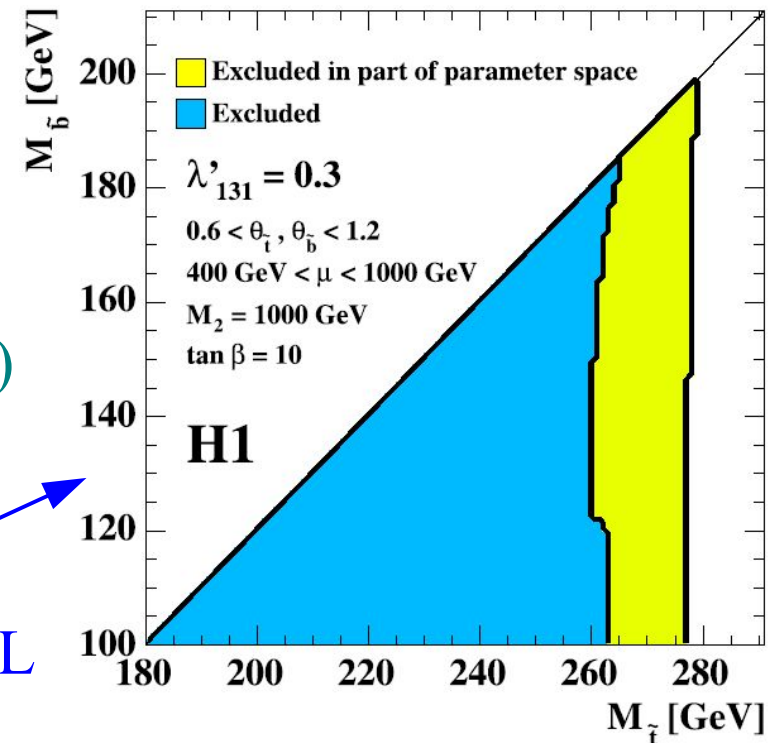
3jets+p_{T,miss}

Used data set: 68 pb-1 ($\sqrt{s}=319$ GeV)
+ 38 pb-1 ($\sqrt{s}=301$ GeV)

Excess in jet+ μ +p_{T,miss} (obs/exp=8 / 2.7±0.5)
not confirmed by other channels.

Limits in $m(\tilde{b})$ - $m(\tilde{t})$ plane:

$m(\tilde{t})$ up to 275 GeV excl. at 95% CL



ZEUS: Gaugino Search

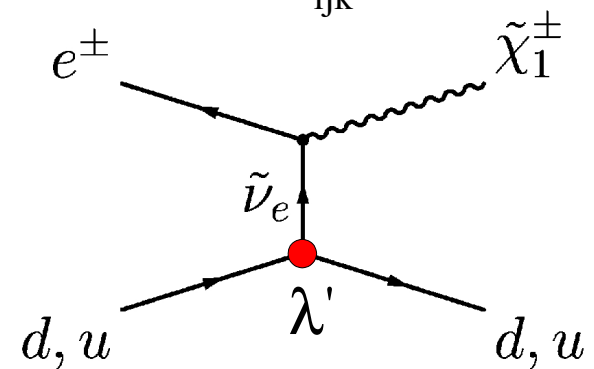
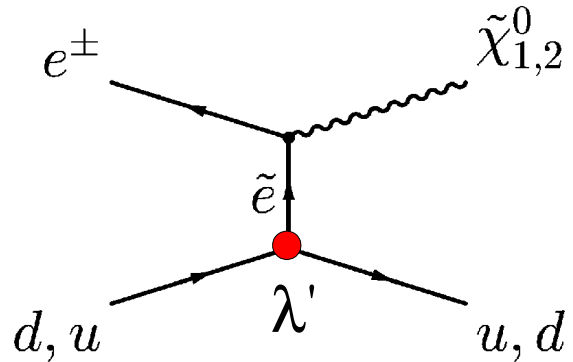
If $M_{\text{squark}} \gg M_{\text{slepton}}$:

s-channel suppressed \Rightarrow t-channel dominant, probing λ'_{ijk}

Gaugino production:

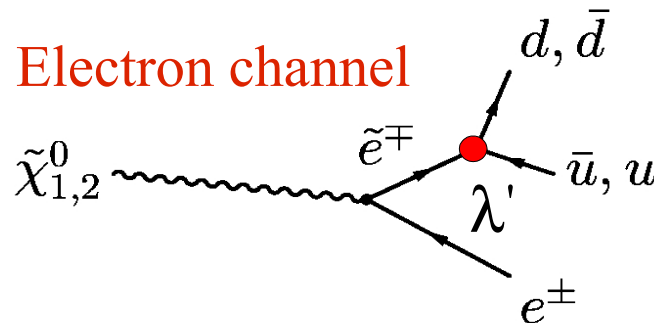
$$\sigma \sim (\lambda')^2$$

Independent of squark masses!



Gaugino Decay:

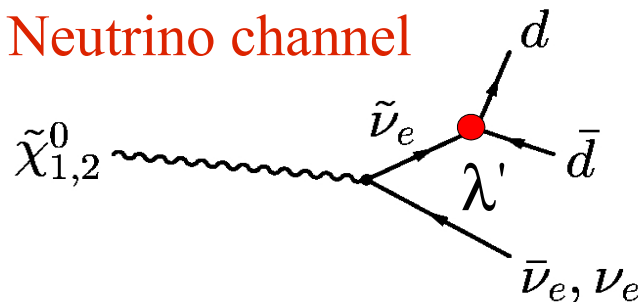
Electron channel



BRs add up to almost 100%.

$\tilde{\chi}^\pm$ decay to same final states

Neutrino channel



Gaugino Search: Selection

Electron channel shown at SUSY2005.

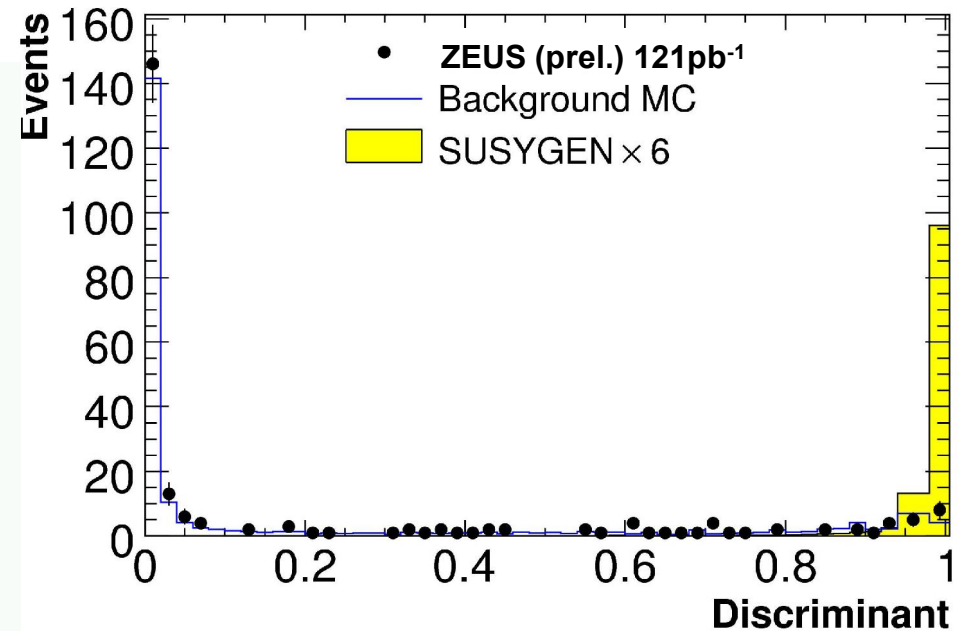
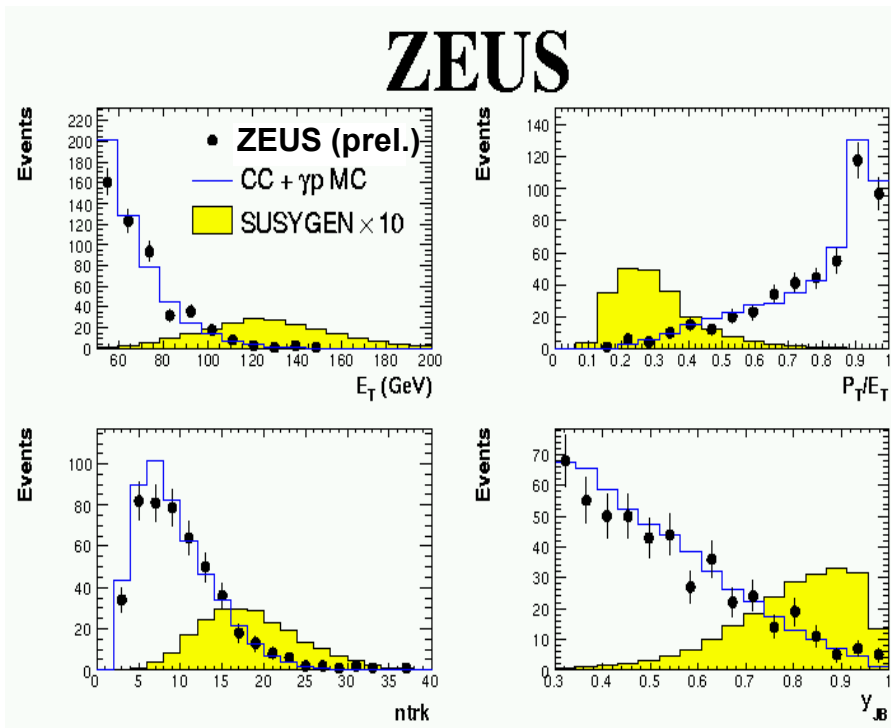
Neutrino channel:

- $E_T > 50$ GeV
- $P_T > 20$ GeV
- ≥ 1 jet ($p_T > 10$ GeV)
- reject events with electron

new channel included!

Analysed ZEUS data: 121pb^{-1}

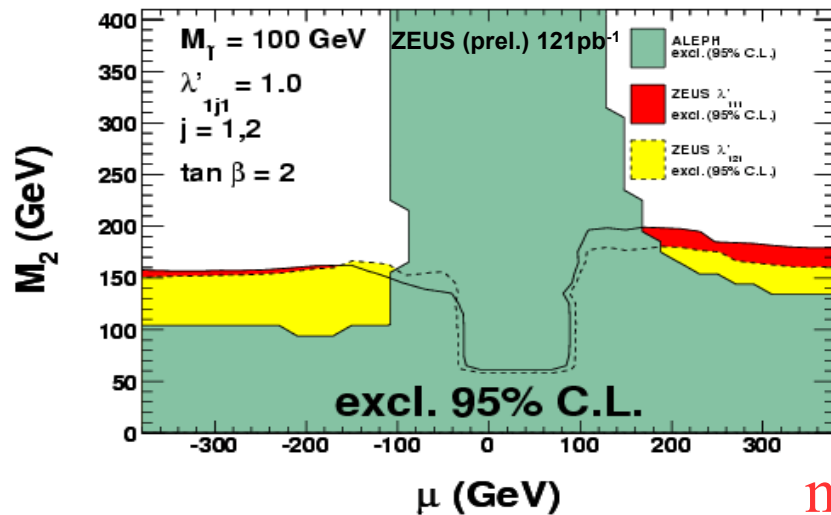
Discriminant method used to optimise signal-to-background.



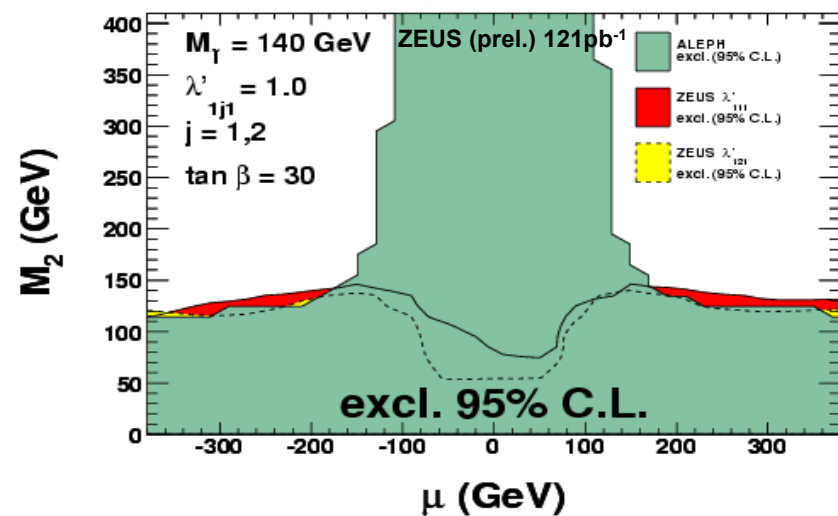
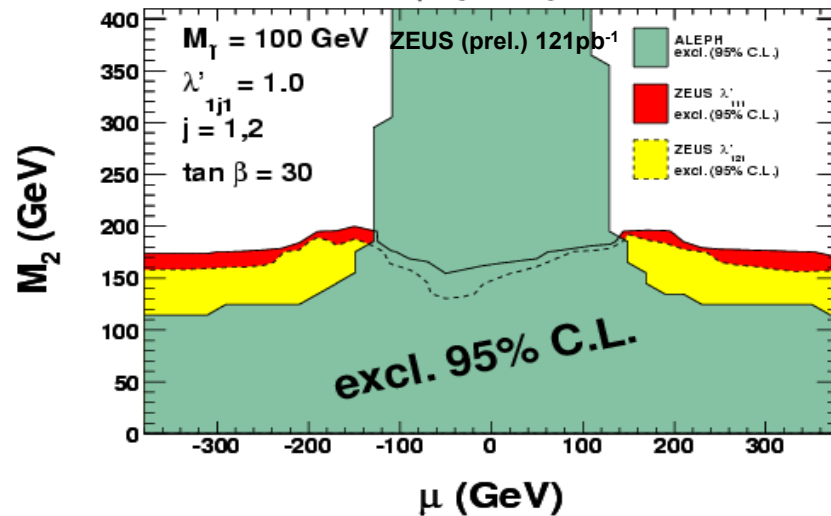
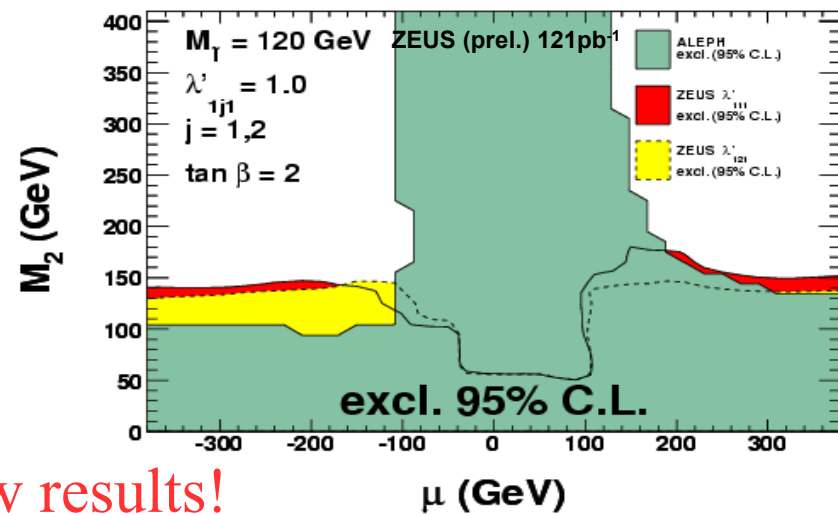
Data shows no signal.

Gaugino Search: Results

Results from both channels combined to calculate limits in MSSM:



new results!



Excluded region from scan with $m_{\chi_{\pm}} \leq 103 \text{ GeV}$ (LEP limit).

H1: Gravitino Search

MSSM \rightarrow GMSB: LSP is gravitino

Signature:

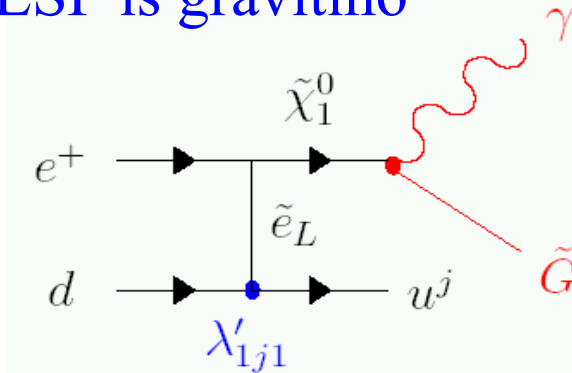
isol. $\gamma + p_{T, \text{miss}} + 1 \text{ jet}$

No deviation from SM observed.

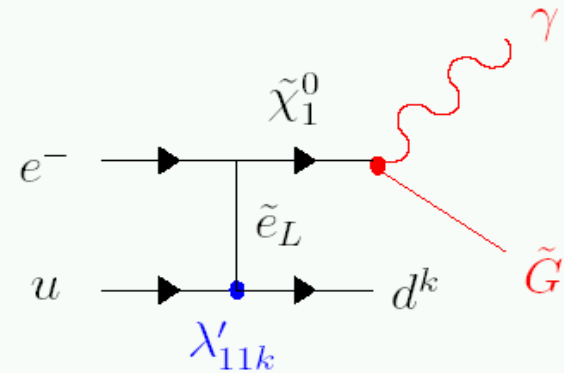
Used Lumi:

e^+p : 64 pb^{-1}

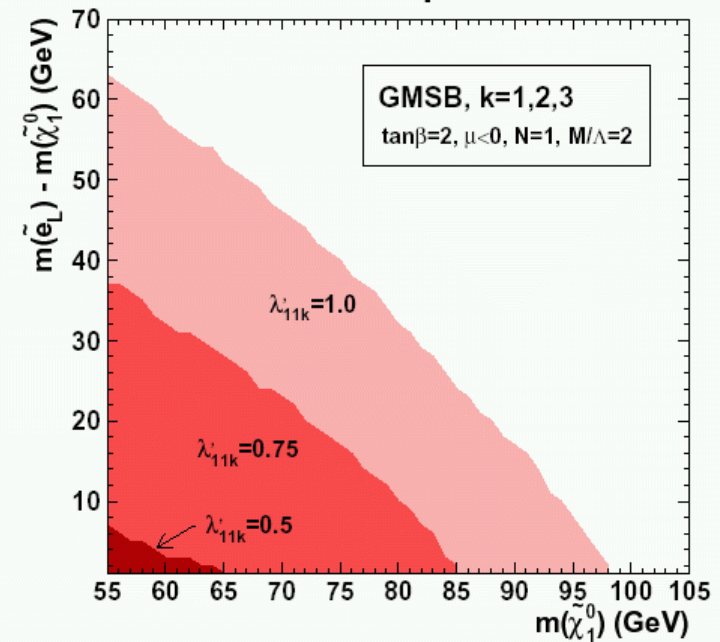
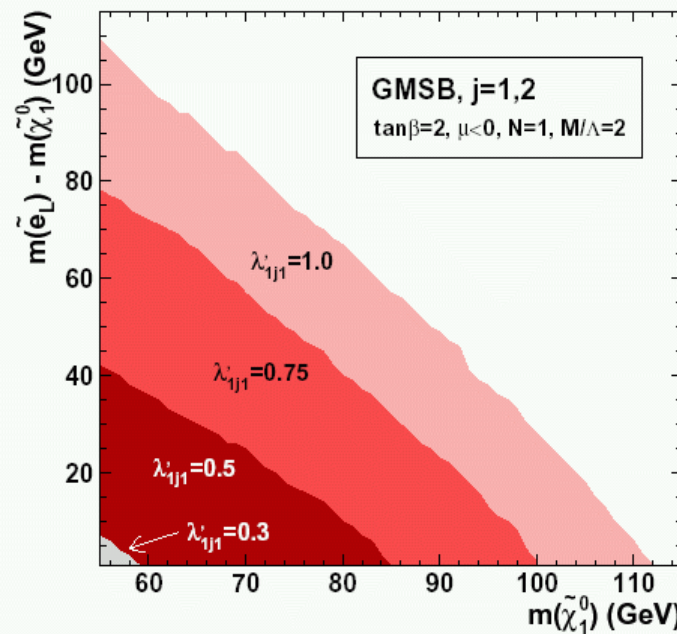
e^-p : 14 pb^{-1}



H1 e^+p



H1 e^-p



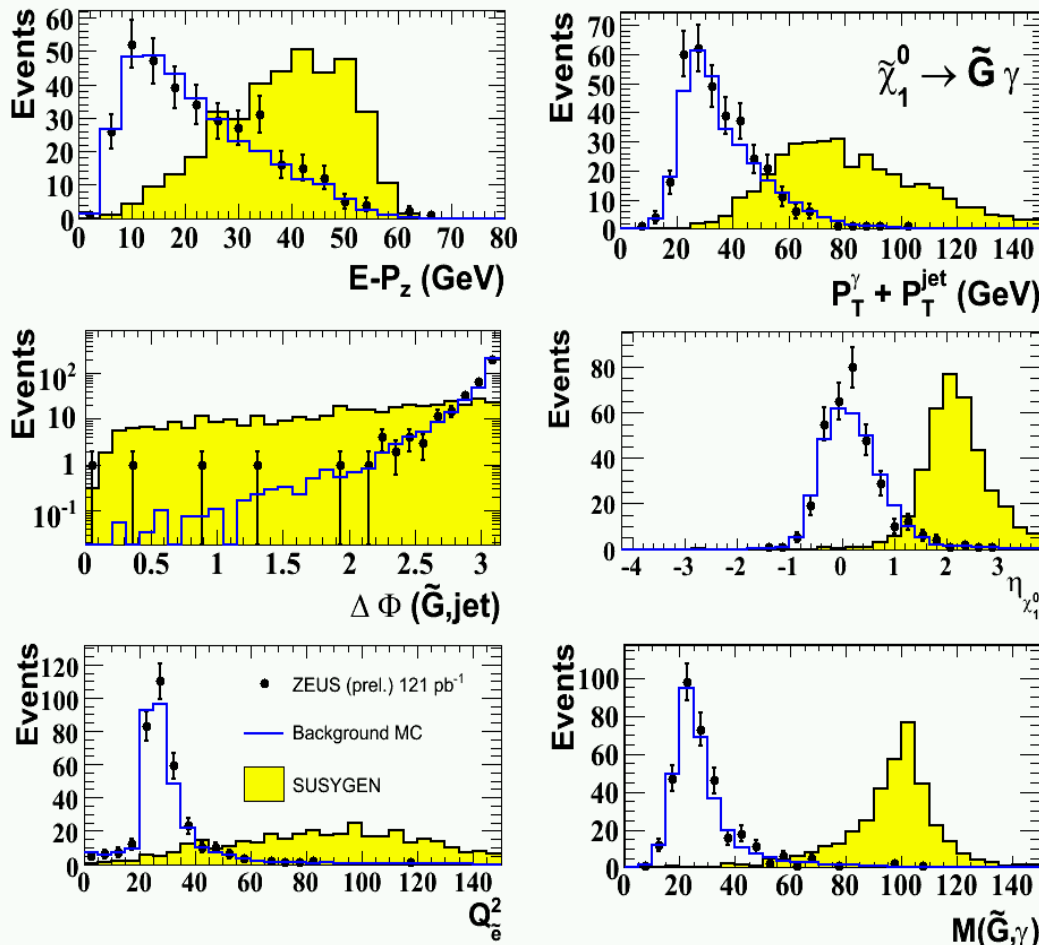
High squark masses \rightarrow no constraints from APV, CCU \rightarrow λ' can be large!

Gravitino Search by ZEUS

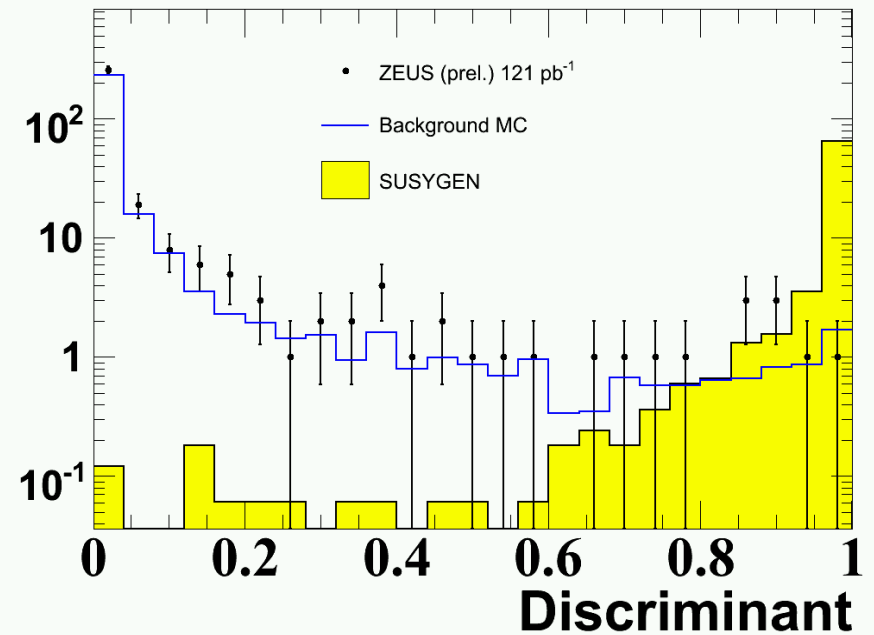
Using multivariate discriminant method to optimise signal-to-background.
 Variables used for discriminant:

ZEUS

Used Lumi: 121 pb⁻¹ (e⁺p and e⁻p !)



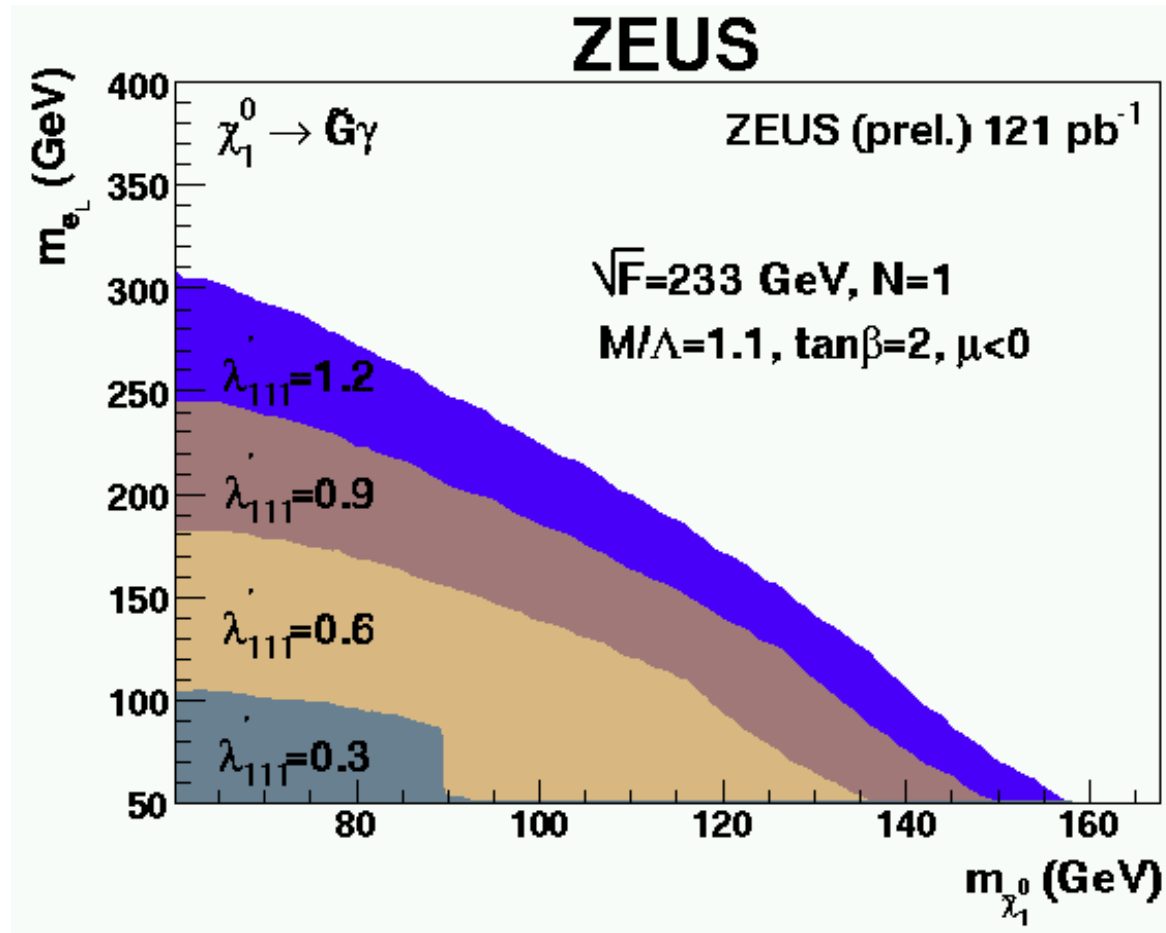
ZEUS



No excess in signal region.

Gravitino Search by ZEUS

Limits for different strength of λ' coupling:



new result!

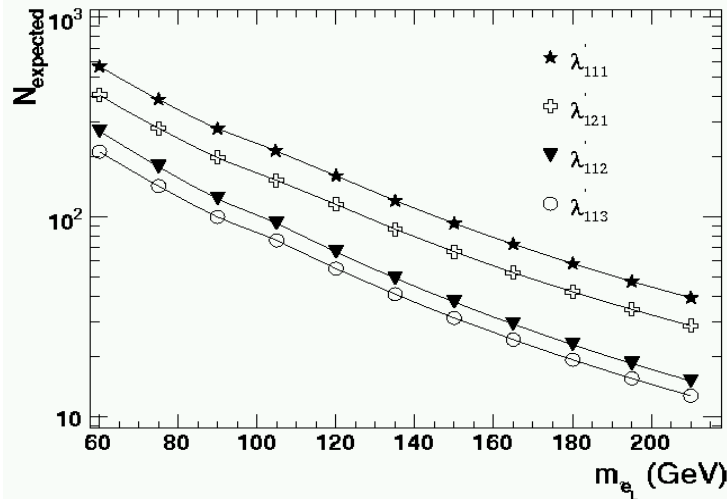
Compared to H1 result:

- More luminosity used
- Also $e\bar{p}$ data included (larger coupling)
- Use of discriminant gives higher sensitivity
- Slightly different parameters

For $\lambda'_{111}=1$ masses up to $m(\tilde{e}) < 260$ GeV,
 and $m(\tilde{\chi}) < 150$ GeV can be excl. at 95% CL.

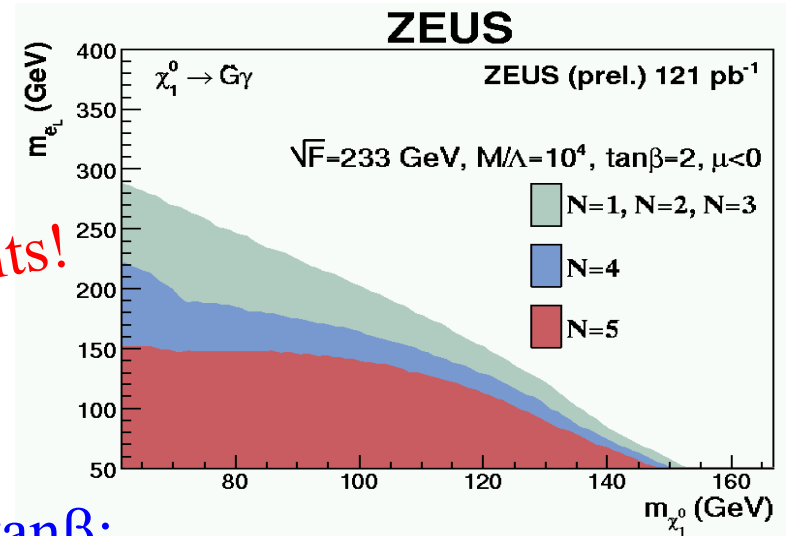
Gravitino Search by ZEUS

Limits for different couplings:

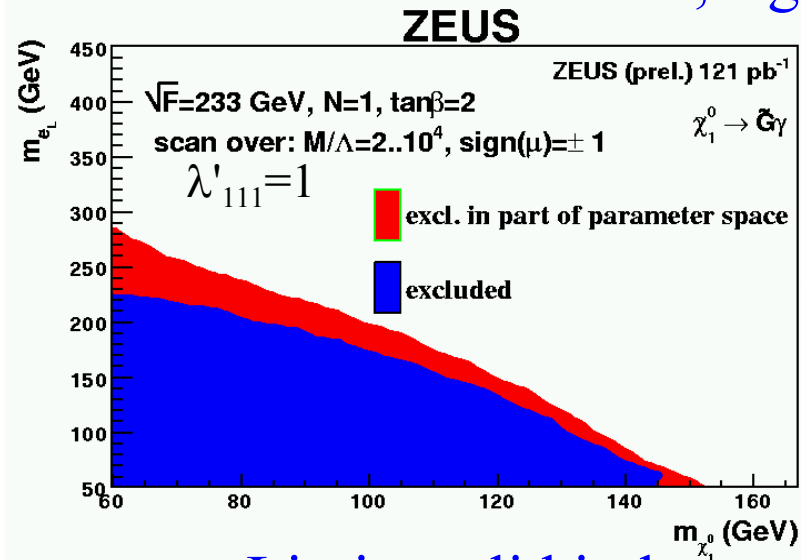


new results!

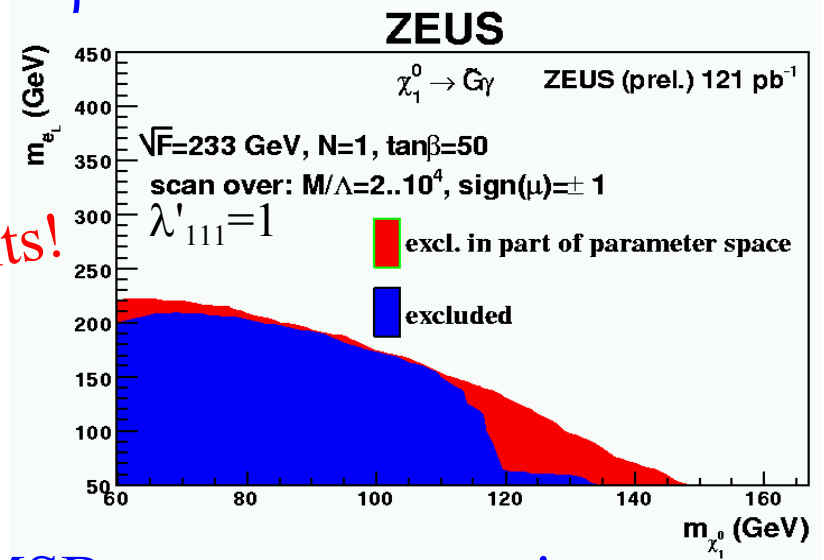
Limits for different N:



Limits for different M/Λ , $\text{sign}(\mu)$ and $\tan\beta$:



new results!



→ Limits valid in large part of GMSB parameter space!

Conclusions

- HERA is an ideal place to search for RPV supersymmetry
- Many searches for supersymmetry have been performed with HERA I data
 - Squark production in MSSM and mSUGRA
 - Gaugino production in MSSM
 - Gravitinos in GMSB
 - No evidence for supersymmetry was found.
- HERA II running very efficiently
 - Collected HERA II luminosity already twice of HERA I!
 - Search results from HERA II expected soon!